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(54) Device alignment methods.

(57)   First and second devices, such as a laser (11)
and an optical fiber (12), are aligned by first
positioning the laser on an x - y - z table (13)
(such a table is capable of responding to electri-
cal signals to make precise movements in mutu-
ally orthogonal x,y and z directions). The laser
beam is imaged onto a machine vision camera
(19) which develops signals representing the
image of the laser beam and directs them to a
computer (16). The computer analyzes the sig-
nal, calculates the center of the image, and
determines from such calculation any devia-
tions in the x and y directions of the position of
the laser from its desired alignment position.
Next, the optical fiber (12) is imaged on a
machine vision camera (17). Signals from the
camera representative of the image of the opti-
cal fiber end are directed to the computer (16)
which calculates the center of the image and
determines any deviation from its desired posi-
tion. Finally, the x - y - z table is moved such that
the laser is in approximate alignment with the
optical fiber end, and signals from the computer
are used to make fine adjustments of the posi-
tion of the x - y - z table to compensate for the
deviations of the laser from its assigned posi-
tion and deviations of the optical fiber end from
its assigned position.

FIG. 1

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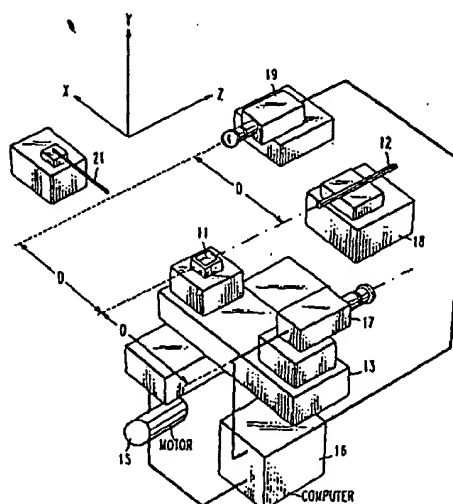
Technical Field

This invention relates to methods and apparatus for aligning devices and, more particularly, to methods for aligning optical or photonics devices with a high degree of precision.

Background of the Invention

With the advent of optical communications systems, considerable development work has been done on methods for assembling components of such systems. One of the problems associated with assembling such components is a need for precise alignment of optical elements such as lenses, optical fibers, lasers, mirrors and photodetectors. It is important that factory methods be developed for assembling optical devices and packages in an efficient manner, with a minimum requirement of operator skill, but with an exceedingly high degree of precision.

In making laser modules, for example, it is necessary to bond an optical fiber in precise alignment to a semiconductor laser to maximize the portion of the laser output that is directed into the end of the optical fiber. For obtaining maximum optical coupling, it is typically desired that the center of the optical fiber be aligned with the center of the laser to within tolerances of less than one micron. The most common way of making this alignment is a process known as "active alignment," in which light is emitted from the laser, with the position of the end of the optical fiber near the laser being adjusted until the light transmitted through the fiber reaches a maximum.

For automatic assembly of laser modules using active alignment, it is usually required that some apparatus be devised for causing one end of the optical fiber to scan a small area intercepting the laser output beam, while a photodetector at the output end of the fiber detects the location at which maximum light transmission occurs. When that position has been determined, the optical fiber is permanently bonded to the laser and enclosed within a package.

It can be appreciated that mechanical scanning of an optical device such as an optical fiber is inherently time consuming, and, as the need for greater volumes of mass-produced components increases, such time consumption becomes increasingly detrimental. Of course, the alternative of manually adjusting the fiber orientation to achieve active alignment is even less practical because of the operator skill required, as well as the time consumed. Accordingly, there is a continued, long-felt need for better and more efficient methods for aligning, assembling and mass-producing optical and/or photonics components.

Summary of the Invention

In accordance with an illustrative embodiment of

the invention, first and second devices, such as a laser and an optical fiber, are aligned by first positioning the laser on an x-y-z table (such a table is capable of responding to electrical signals to make precise movements in mutually orthogonal x,y and z directions). The laser beam is imaged onto a machine vision camera which develops signals representing the image of the laser beam and directs them to a computer. The computer analyzes the signal, calculates the center of the image, and determines from such calculation any deviations in the x and y directions of the position of the laser from its desired alignment position. Next, the optical fiber is imaged on a machine vision camera. Signals from the camera representative of the image of the optical fiber end are directed to the computer which calculates the center of the image and determines any deviation from its desired position. Finally, the x-y-z table is moved such that the laser is in approximate alignment with the optical fiber end, and signals from the computer are used to make fine adjustments of the position of the x-y-z table to compensate for the deviations of the laser from its assigned position and deviations of the optical fiber end from its assigned position. After the laser and the optical fiber end are aligned in close proximity, they are bonded together in permanent alignment for subsequent packaging.

Commercially available equipment can be used to move the laser very rapidly between its position at which it is imaged and the position in which it is aligned. Very rapid determinations of deviations from prescribed alignment can be made, and signals generated for adjusting the position of the laser to be in precise alignment to the optical fiber. Little operator skill is required for the process and it can be accomplished repetitively and rapidly as is required for volume mass-production.

These and other objects, features and advantages of the invention will be better understood from a consideration of the following detailed description taken in conjunction with the accompanying drawing.

Brief Description of the Drawing

FIG. 1 is a schematic view of apparatus for aligning a laser with an optical fiber in accordance with an illustrative embodiment of the invention;
FIG. 2 is an illustration of the apparatus of FIG. 1 at another phase of its operation;
FIG. 3 is a graphical illustration of alignment deviations; and
FIG. 4 is a schematic view showing how the laser and optical fiber of FIGS. 1 and 2 may be bonded together.

Detailed Description

The drawings are not necessarily to scale and

have been simplified to aid in clarity of exposition. Referring now to FIG. 1, there is shown schematically an illustrative embodiment of the invention comprising apparatus for aligning and bonding together a semiconductor laser 11 and an optical fiber 12. The laser is mounted on an x-y-z table 13 which is capable of moving the laser in orthogonal x-y-z directions either in large increments or in incremental steps as small as 0.01 microns. The table is driven by a motor schematically shown at 15 which is controlled by signals from a computer 16. The x-y-z table may be of a type which is commercially available from the Anorad Corporation of Hauppauge New York, U.S.A. Also mounted on the x-y-z table is a machine vision camera 17.

The optical fiber 12 is in approximate axial alignment with the laser 11 as is required for bonding them together, but it is located on a stationary support 18. Also located on a stationary support is a machine vision camera 19. Machine vision cameras is 17 and 19 are preferably conventional television cameras, but their function is to generate machine-readable video signals rather than video signals for visual display. Accordingly, any device, such as an array of photodetectors, capable of generating machine-readable signals representative of an image could be used as a machine vision camera.

The outputs of machine vision cameras 17 and 19 are connected to the computer 16. The aligned photodetector and fiber are separated from camera 17 by a distance D and from camera 19 by a distance D. Also separated by a distance D from the laser 11 is an electronic probe 21 for biasing the laser 11.

While FIG. 1 shows the laser 11 being in alignment with the central axis of the optical fiber, such alignment can initially be made only approximately, and it is the purpose of this embodiment to adjust the alignment to be exact to within a fraction of a micron. Specifically, it is intended that the elements be aligned to maximize the portion of light emitted from the laser that is intercepted and transmitted by the core of the fiber which lies along the central axis of the fiber. The first step in accomplishing this function is to move the x-y-z table 13 in the x direction a distance D, to the position shown in FIG. 2. At this position, the probe 21 contacts the laser 11 which, when appropriately energized, emits light in the direction of machine vision camera 19. In the position shown in FIG. 2 the laser 11 is in approximate alignment with machine vision camera 19, and consequently the emitted laser beam is easily within the field of view of the camera 19. The camera 19 contains lenses for imaging the laser light, and an electron beam for scanning the image to generate a video signal representative of the image.

The video signal is directed to a computer 16 which is programmed to locate the geometrical center of the image. Machine vision systems including computers are well-known in the art, and one that is ca-

pable of producing the appropriate signals is a system available from Cognex, Inc., Needham, Massachusetts. Referring to FIG. 3, the computer, after determining the center of the laser beam, compares its location, such as location 22, with a location 23 that would represent perfect alignment. One can see that, with the ordinates shown, 22 is at approximately $x=-1$ and $y=+3$ with respect to location 23. The difference of position of locations 22 and 23 represents the misalignment, or deviation from precise alignment, of the laser beam.

In the same manner, a machine vision camera 17 generates signals representative of the image of the end of optical fiber 12 which are directed to the computer for determination of the geometric center at the end of fiber 12. Notice that in the position shown in FIG. 2, camera 17 is in approximate alignment with optical fiber 12, and therefore the end of the optical fiber, in a section taken transverse to the fiber central axis, is within the field of view of the camera 17. Referring to FIG. 3, the calculated center of the end of optical fiber 12, which normally coincides with the center of the fiber core, may be determined to be at location 24 which is at $x=+1, y=+2$ with respect to a location 23 which represents perfect alignment. The x-y-z table 13 is extremely accurate in its mechanical movements so it is capable of returning to the exact position shown in FIG. 1.

The computer generates a correction signal representative of the difference in alignment of points 22 and 24 of FIG. 3. That is, in the example shown, the computer generates a corrective signal to move the location 22 of laser 11 in the x direction a distance $x=+2$ and in the y direction a distance $y=-1$. This makes end points 22 and 24 to be coincident and brings the laser 11 into substantially exact alignment with the optical fiber 12. This function can be stated as follows: If the initial misalignment of the laser is A_x, A_y and the initial misalignment of the fiber is B_x, B_y, the computer generates a corrective signal equal to $(A_x-B_x), (A_y-B_y)$ to bring the laser into alignment with the fiber. Programming the computer to perform this simple function is within the skill of the worker in the art.

After alignment, the computer causes the x-y-z table to move in the z direction to bring the laser into sufficient proximity with the optical fiber 12 that they can be bonded. This is schematically shown in FIG. 4 where a mounting element 26 is shown as being bonded both to laser 11 and optical fiber 12. The bonding can be made by epoxy, solder, or other methods as are known in the art and can be done manually or automatically through the use of robotic apparatus known in the art.

An advantage of the alignment scheme that has been described is that it can be operated automatically at a higher production rate than the active alignment method of aligning an optical fiber with a laser.

This is important in the mass production of laser assemblies where many such identical assemblies may be required for a complex optical communications system. While a preferred method of aligning a laser with a fiber has been described, it is to be understood that other devices such as lenses, mirrors, photodetectors, etc., could be aligned and assembled by the same method and that significant deviations from the method shown could be made. In the embodiment described, the laser beam is imaged on the machine vision camera, but it is to be understood that this is the equivalent of imaging the laser device on the machine vision camera and that the method aligns the laser device, as well as the beam, with the optical fiber. In practice, aligning the laser while it emits light is preferable because it assures alignment of the center of emitted light with the center of the optical fiber. While it is advantageous to have the two cameras each located a distance D from the aligned fiber and laser as shown so that one movement of the x-y-z table will bring both cameras into alignment, such configuration is not essential. The invention can be used to align laser arrays or photodetector arrays with fiber bundles or lens arrays. Other embodiments and modifications may be made by those skilled in the art without departing from the spirit and scope of the invention.

Claims

1. A method for aligning a first device with a second device comprising the steps of:

   positioning a first device (11) on a movable x-y-z table (13);

   imaging the first device in a machine vision camera (19);

   directing signals from the machine vision camera representative of the image of the first device to a computer (16);

   using the computer to calculate the center of the image of the first device and to determine from such calculation any deviations in x and y orthogonal directions of the position of the first device from a first predetermined position;

   imaging the second device (12) in a machine vision camera (17);

   directing signals from the machine vision camera (17) representative of the image of the second device to said computer;

   using the computer (16) to calculate the center of the image of the second device and to determine from such calculation any deviations in the x and y directions of the position of the second device from a second predetermined position;

   moving the movable table such that the first device is in alignment with the second device, and using signals from the computer to make fine adjustments of the movable table to compensate for said deviations of the first device from the first predetermined position and the second device from the second predetermined position.

2. The method of claim 1 wherein:

   the first device (11) is imaged in a first machine vision camera (19); and

   the second device (12) is imaged in a second machine vision (17) camera that is different from the first machine vision camera

3. The method of claim 2 wherein:

   the first and second machine vision cameras are television cameras.

4. The method of claim 2 wherein:

   the second machine vision camera is mounted on the movable table along with the first device;

   prior to imaging the first device in the first machine vision camera, the movable table is moved such that the first device is in approximate alignment with the first machine vision camera; and

   prior to imaging the second device in the second machine vision camera, the movable table is moved such that the second device is in approximate alignment with the second machine vision camera.

5. The method of claim 4 wherein:

   the first and second machine vision cameras are mounted appropriately such that a single movement of the movable table simultaneously brings the first device into approximate alignment with the first machine vision camera and the second device into approximate alignment with the second machine vision camera.

6. The method of claim 5 wherein:

   the first device is a light-emitting device;

   the step of imaging the first device comprises the step of imaging light emitted from the first device in the first machine-vision camera; and

   the second device is an optical fiber.

7. The method of claim 5 wherein:

   when the first device is approximately aligned with the second device, the x distance of the first and second devices from the first machine vision camera is a distance D, and the distance of the first and second devices from the second machine vision camera in the opposite x direction is a distance D, whereby movement of

the first device in the *x* direction a distance D to bring it into the field of view of the first machine vision camera also brings the second device into the field of view of the second machine vision camera.

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8. The method of claim 1 wherein:

    steps of calculating and using said calculations comprise the steps of using the computer to calculate the respective centers of the first and *10* second devices, comparing such calculated centers to predetermined locations which represent alignment of the first and second devices, generating corrective electrical signals representing any deviations of the locations of the centers of *15* the first and second devices, and using the corrective electrical signals to adjust a motor which moves the *x-y-z* table so as to align the centers of the first and second devices.

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9. The method of claim 8 wherein:

    the motor constitutes part of the *x-y-z* table;

    the first and second machine vision cameras are television cameras; *25*

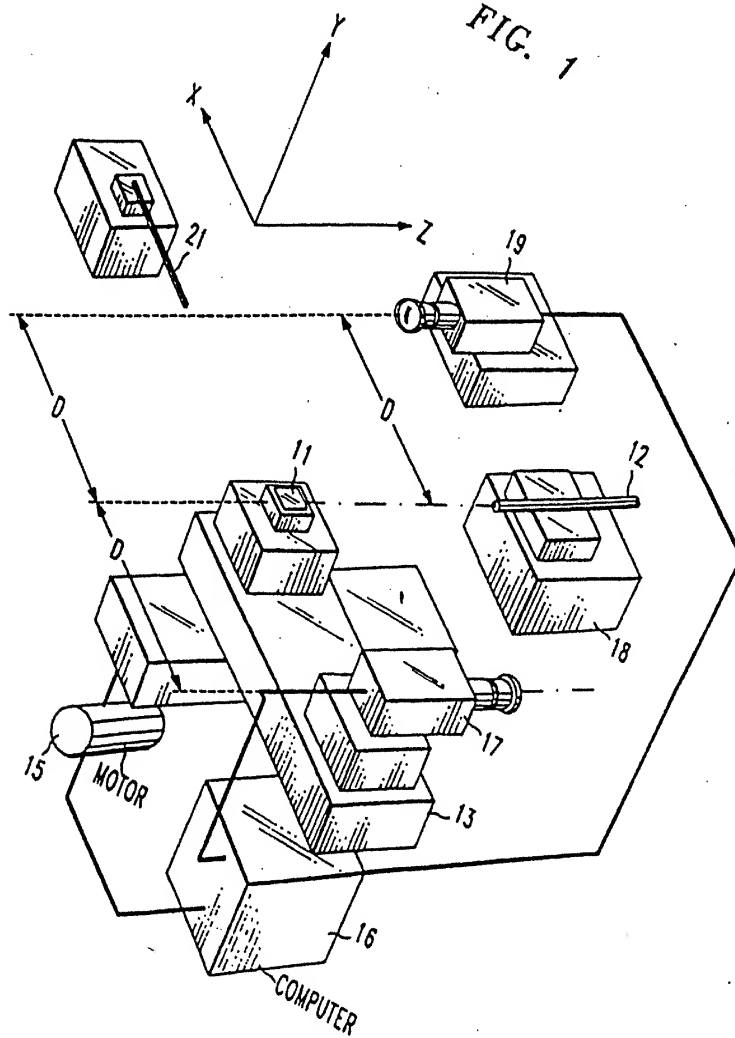   and the first and second devices are optical devices.

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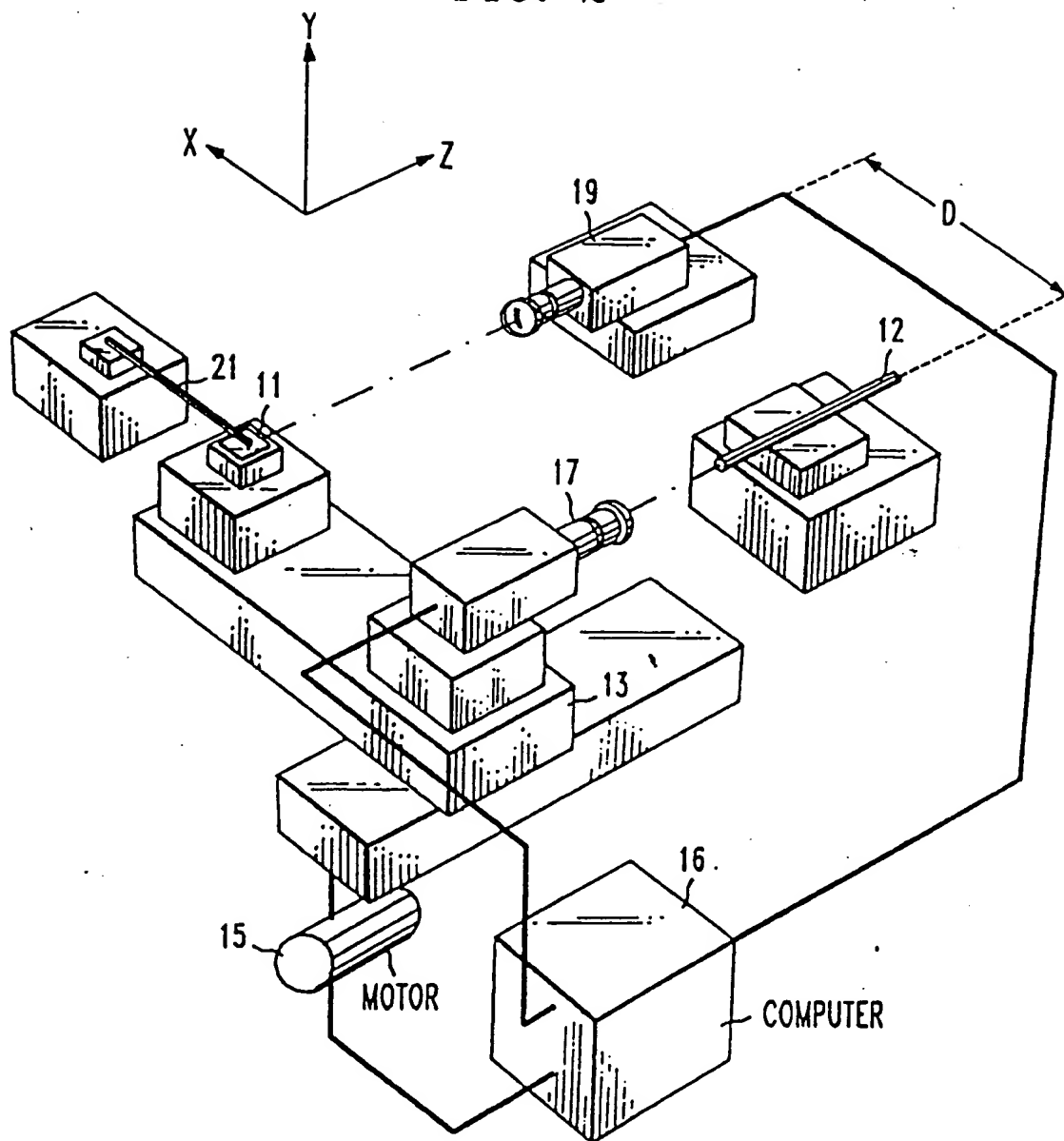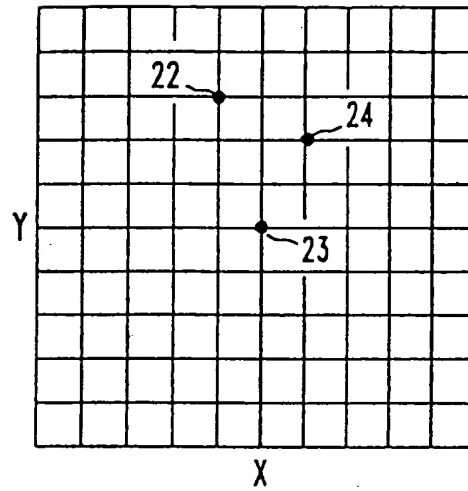*35*
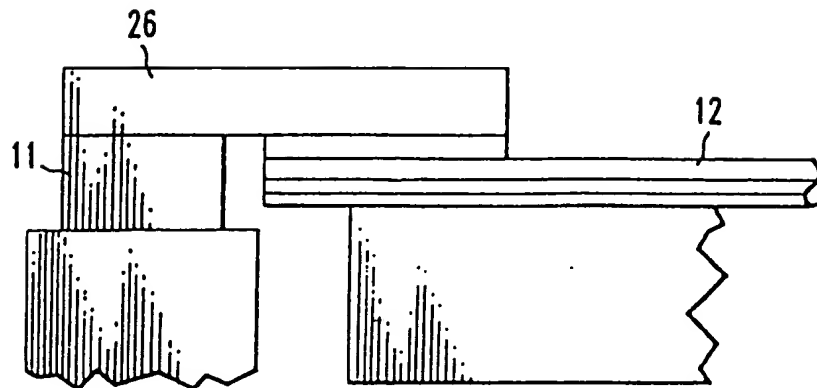
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FIG. 1

FIG. 2

FIG. 3

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number

	DOCUMENTS CONSIDERED TO BE RELEVANT		EP 93307300.9
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	US - A - 4 854 667 (EBATA et al.) * Column 2, line 19 - column 3, line 47; column 4, line 3 - column 5, line 30 *	1-3,8, 9	G 02 B 7/00 //G 02 B 6/42
A	--	4,6	
Y	EP - A - 0 269 337 (AT & T) * Column 2, line 42 - column 5, line 23 *	1-3,8, 9	
A	-- US - A - 4 850 668 (HAKIMI) * Column 2, line 67 - column 4, line 24 *	1,6	
A	-- DE - A - 3 705 749 (AT & T) * Fig. 1 * ----	1,6	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5) G 02 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	14-01-1994	GRONAU

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document